

EFFECT OF SILICON ON ACTIVITY COEFFICIENTS OF P, BI, CD, SN, AND AG IN LIQUID Fe-Si, AND IMPLICATIONS FOR DIFFERENTIATION AND CORE FORMATION. K. Righter¹, K. Pando², D.K. Ross³,

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Introduction: Cores of differentiated bodies (Earth, Mars, Mercury, Moon, Vesta) contain light elements such as S, C, Si, and O. We have previously measured small effects of Si on metal-silicate partitioning of Ni and Co [1,2], and larger effects for Mo, Ge, Sb, As [2]. The effect of Si on many siderophile elements could be an important, and as yet unquantified, influence on the core-mantle partitioning of SE. Here we report new experiments designed to quantify the effect of Si on the partitioning of Bi, Cd, Sn, Ag, and P between metal and silicate melt. The results will be applied to Earth, Mars, Mercury, Moon, and Vesta, for which we have excellent constraints on the mantle Bi, Cd, Sn, Ag, and P concentrations from mantle and/or basalt samples.

Experimental: Experiments were carried out using a piston cylinder apparatus and run conditions of 1 GPa and 1600 °C. The starting materials comprised natural basaltic silicate (70% by mass) mixed with metallic Fe + 5% Bi and Cd or Sn and Ag (30% by mass). Silicon metal was also added to the metallic mixture at 2, 4, 6, and 10 %, to alloy with the Fe liquid and create an FeSi alloy of variable Si content. The MgO capsule reacts with the silicate melt to form more MgO-rich liquids that have 22-26 wt% MgO (Fig. 1).

Analytical: Experimental metals (Fe, Bi, Cd, Sn, Ag, P, Si) and silicates (major elements) were analyzed using electron microprobe analysis (EMPA) at NASA-JSC utilizing a variety of mineral and glass standards with 15 kV and 20 nA conditions. We plan to measure Bi, Cd, Sn and Ag in the glass (likely <100 ppm) in the future using LA-ICP-MS.

Results: The Si-free samples equilibrated at fO_2 values of IW-2, and where P is largely stable in the silicate melt as P_2O_5 . The experiments with most Si-rich metals equilibrated at fO_2 values as low as IW-6, where the Fe and P are nearly entirely reduced to the metal, and P content of the silicate melt is very low (Fig. 2). Measured P and Fe in metal and silicate were used to calculate metal (met) - silicate (sil) exchange K_d according to: $P_2O_5^{sil} + 5Fe^{met} = 2P^{met} + 5FeO^{sil}$. From this equilibrium, activity coefficients are derived for P in FeSi liquids (see [2]). Our results show that Si causes a substantial decrease in the metal-silicate partition coefficient. As a result, the Si content of the metal must be stipulated in any core formation model for a differentiated body. Even small amounts of Si cause 10x lowering of the activity coefficient of P in Fe metal. We will combine these results for P (as well as new results for Sn and Ag) with those for S and C [3,4] and apply an activity model to differentiated bodies such as Earth, Mars and 4 Vesta.

References: [1] Tuff, J. et al. (2011) GCA 75, 673-690. [2] Righter, K. et al. (2017) GCA 198, 1-16. [3] Wood, B.J. et al. (2014) GCA 145, 248-267; [4] Lupis, C. (1983) Chemical Thermodynamics of Materials, Elsevier, 581 pp.

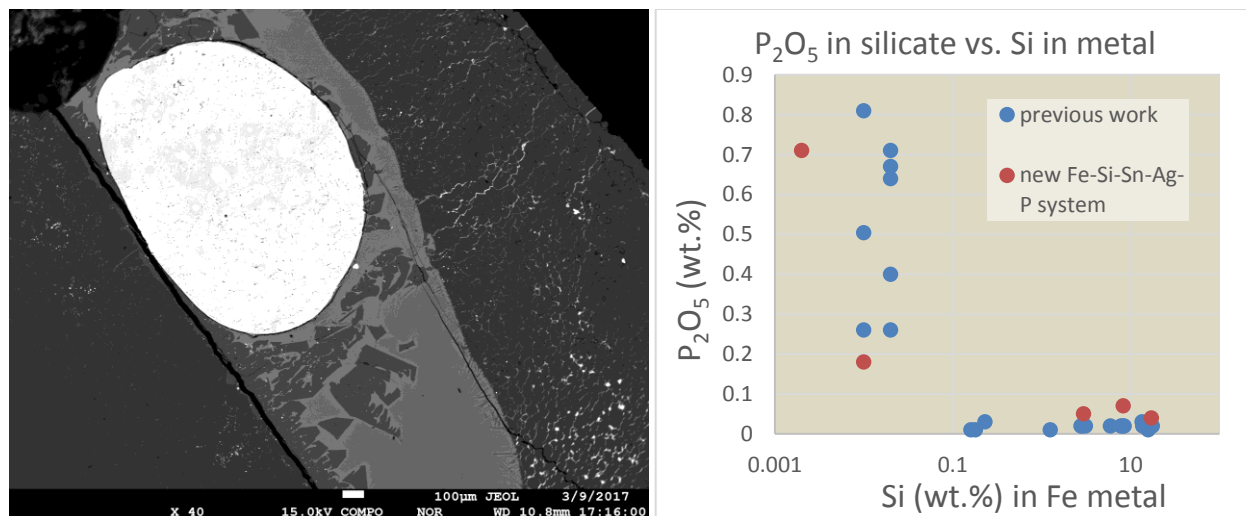


Figure 1 (left): Experiment equilibrated at 1 GPa, 1600 C, with ~ 17 wt% Si in the metal. Bright rounded phase is Fe-Si-P-Bi-Cd alloy and light gray phase is silicate melt; some MgO capsule material (darkest phase) is also present in the silicate melt.

Figure 2 (right): Negative correlation between Si content of the Fe metal and the P_2O_5 content of the silicate melt. Our new results for the experiments with Fe-Sn-Ag-Si-P show similar behavior to previous results of [2].